PART TWO

How the Brain Develops and How the Circuits and Chemistry of ADD Arise

6

Different Worlds: Heredity and the Environments of Childhood

The family I grew up in was not the family my brothers grew up in. They grew up in a family that was on the road constantly, never in the same place longer than a couple of months at best. They grew up in a family where they watched the father beat the mother regularly, battering her face until it was a mortified, blue knot. They grew up in a family where they were slapped and pummelled and belittled for paltry affronts... I grew up in a world so different from that of my brothers, I may as well have grown up under a different surname.

– MIKAL GILMORE, *Shot in the Heart*

A GENETIC FUNDAMENTALISM permeates public awareness these days. It may be summed up as the belief that almost every illness and every human trait is dictated by heredity. Simplified media accounts, culled from semidigested research findings, have declared that inflexible laws of DNA rule the biological world.

It was reported in 1996 that according to some psychologists, genes determine about 50 percent of a person's inclination to experience happiness. Social ability and obesity are two more among the many human qualities now claimed to be genetic. "Each week ... brings the discovery of a gene that is associated with some disease or trait," noted a tongue-in-cheek contributor to *The New York Times*. "With thousands yet to be discovered, you can just imagine what is out there, or in there...The Line Dancing Gene. The Loves British Cuisine Gene...The Tendency to Go on TV Talk Shows and Embarrass Yourself Gene..."

True or not, narrow genetic explanations for ADD and every other condition of the mind do have their attractions. They are easy to grasp, socially conservative and psychologically soothing. They raise no uncomfortable questions about how a society and culture might erode the health of its members, or about how life in a family may have affected a person's physiology or emotional makeup. As I have personally experienced, feelings of guilt are almost inevitable for the parents of a troubled child. They are all too frequently reinforced by the uninformed judgments of friends, neighbors, teachers or even total strangers on the bus or in the supermarket. Parental guilt, even if misplaced, is a wound for which the genetic hypothesis offers a balm.

There is a significant hereditary contribution to ADD—sensitivity, subject of the next chapter—but I do not believe any genetic factor is *decisive* in the emergence of ADD traits in any child.[1] Genes are codes for the synthesis of the proteins that give a particular cell its characteristic structure and function. They are, as it were, alive

and dynamic architectural and mechanical plans. Whether the plan becomes realized depends on far more than the gene itself. It is determined, for the most part, by the environment. To put it differently, genes carry *potentials* inherent in the cells of a given organism. Which of multiple potentials become expressed biologically is a question of life circumstances.

Were we to adopt the medical model—only temporarily, for the sake of argument—a genetic explanation by itself would still be unsuitable. Medical conditions for which genetic inheritance are fully or even mostly responsible, such as muscular dystrophy, are rare. "Few diseases are purely genetic," says Michael Hayden, a geneticist at the University of British Columbia and a world-renowned researcher into Huntington's disease. "The most we can say is that some diseases are strongly genetic." Huntington's is a fatal degeneration of the nervous system based on a single gene that, if inherited, will almost invariably cause the disease. But not always. Dr. Hayden mentions cases of persons with the gene who live into ripe old age without any signs of the disease itself. "Even in Huntington's, there must be some protective factor in the environment," Dr. Hayden says.

Genes can be activated or turned off by factors in the environment. In the Cree population of northwestern Ontario, for example, diabetes is found at a rate five times the Canadian national average, despite the traditionally low incidence of diabetes among native peoples. The genetic makeup of the Cree people cannot have changed in a few generations. The destruction of the Crees' traditional physically active ways of life, the substitution of high-calorie diets for their previous low-fat, low-carbohydrate eating patterns and greatly increased stress levels are responsible for the alarming rise in diabetes rates. Although heredity is involved in diabetes, it cannot possibly account for the pandemic among Canada's native peoples, or among the rest of the North American population, for that matter. We will see that in similar ways changes in society are causing more and more children to be affected by attention deficit disorder.

It is easy to jump to hasty conclusions about genetic information. Some studies have identified certain genes, for example, that are said to be more common among people with attention deficit disorder or with other related conditions, such as depression, alcoholism or addiction. But even if the existence of these genes is proven, there is no reason to suppose that they can, on their own, induce the development of ADD or any other disorder. First, not everyone with these genes will have the disorders. Second, not everyone with the disorders will be shown to carry the genes.

Studies do show that if parents or siblings have ADD, a child in that family will have a greatly increased statistical risk for having ADD as well. ADD is also found more commonly in people whose first-degree relatives are alcoholics or suffer from depression, anxiety, addiction, obsessive-compulsive disorder or Tourette's syndrome. It may appear from such facts that this motley collection of related syndromes is largely hereditary—but to assume that would be like believing that if there are three generations of butchers or bakers or candlestick makers in a family, then meat cutting, baking and candle manufacturing must also be genetic. The family atmosphere in which the child spends the early formative years has a major impact on brain development. It is obvious that brain/mind problems such as ADD are far more likely to develop in families where the parents are struggling with dysfunction or psychological problems of their own. It would be astonishing if children growing up in such unsettled environments did not develop some of the same problems. No genes need be involved at all for these conditions to run in families.[2]

There has been an enduring misconception in psychological studies that comparing identical twins adopted by different families can separate out genetic effects from environmental ones. Because identical twins adopted by different parents are brought up under different circumstances, any similarities in personality traits are assumed to be due to the shared heredity; any differences in character are thought to be caused by differences of environment. This misbelief has heavily influenced the conventional

understanding of attention deficit disorder. It has been shown, for example, that if one of the twin pair has ADD, there is a 50 to 60 percent likelihood that the other will have it as well. The technical term for this likelihood is *concordance*. Such a high degree of concordance is taken to prove a hereditary causation—but only if one ignores the most obvious question: *since identical twins have exactly the same genes, why is the concordance not closer to 100 percent?* Also ignored is a powerful environmental factor: *the adoption itself.*

A consistently available nurturing caregiver is a fundamental need of the human infant. Adoption means separation from the birth mother to whose body, voice, heartbeat and biorhythms a newborn is attuned by the time of birth. We cannot simply discount the devastating effect such separation may have on the impressionable nervous system of the infant. Not a few adoptions—including a significant number of the adoptions examined in published studies—take place several months or longer after birth. Many adoptee infants must endure several changes of caregiver without any single, consistently reliable mothering figure to provide them with a constant, safe relationship. Given that emotional security is an absolute human need in infancy, it is astonishing that adoption is so often forgotten as a possibly crucial influence.

It is also a fact, as a number of adoptive mothers have told me, that even when a newborn adopted at birth is welcomed into a family with the greatest joy and goodwill, some time may have to pass before the truly symbiotic, two-way, physiologically and emotionally attuned relationship is established between mother and infant. Everything being equal, this process is smoother when the mother has herself carried the child within her body for nine months.

There is another environment that adopted twins have shared: nine months in the same uterus. Stress on the mother during pregnancy can unbalance the levels of hormones in her body, particularly of the stress hormone cortisol (cortisone). Both during and after intrauterine life, cortisol directly affects the developing

nervous system. The vast majority of pregnancies ending in adoption occur in mothers under severe stress. They are often unwanted pregnancies, many in teenage girls facing enormous personal, family and social pressures. Infants—twins or single—who are adopted out are likely to have been exposed to high levels of stress hormones throughout the nine months of gestation, a negative influence on their developing brains even before birth.[3]

For such reasons, we can expect all adopted children to be at unusually high risk for psychological problems in general, ADD in particular, without any recourse to genetic explanations. Such is the case. Any health professional working with ADD cases is struck by the large proportion of clients, children or adults, who were adopted in early childhood. A 1982 study found that "the rate of adoption among ADD patients in the clinical population was *8 to 16 times the prevalence of adopted children in the population at large*."[4] If you have ADD, you have a far higher than average chance of having been adopted.

None of this is to say that all babies are born alike, or that there are no important inborn differences in neurological systems from one infant to the next. Mothers report being aware of some characteristic features in the personalities of their babies right from birth, and even before. Some infants, for example, may be more difficult to arouse, others to quiet down. Some may be extremely sensitive, others relatively insensitive, to environmental stimuli such as noise or touch. Stanley Greenspan calls these "patterns of reactivity." In his 1997 volume, *The Growth of the Mind*, Dr. Greenspan observes that the same combination of biological traits—the very same pattern of reactivity—can come to embody many positive human qualities, or may serve as the basis of highly disturbed characteristics. "Whether these features become talents or problems depends, in short, on how the child's nature is nurtured," he writes.[5] The critical difference is the environments in which children are reared.

A view of ADD that recognizes the importance of the environment is inherently optimistic. If environmental causes are largely

responsible for a problem, perhaps environmental approaches can be employed to help resolve it. When we come to the chapters dealing with the treatment of attention deficit disorder, we will see that long-term positive changes are indeed possible, based on changing the environments of children, and even of adults.

A dramatic illustration of how environment shapes personality is the story of the Gilmore family.

On January 17, 1978, in Utah, the convicted double murderer Gary Gilmore was executed by firing squad, his unyielding refusal to appeal his death sentence having gained him a measure of international notoriety. The shattering story of his childhood, blighted by family violence, alcoholism and spite was chronicled later by his brother Mikal Gilmore in the memoir *Shot in the Heart*. Mikal, the youngest of four boys, was born when Gary was eleven years old. If children reared in the same family shared the same environment, the differences between siblings would have to be due to genetic inheritance. In the case of the Gilmores, it is easy to see why Mikal, born at a time when the family was enjoying a period of relative stability, would feel he had been brought up in a different world, why the misery of his childhood, as he put it, had been so radically different from the misery of his brothers' childhood. Even without such vast chasms in experience, the environment of siblings is never the same.

Environment has far greater impact on the structures and circuits of the human brain than was realized even a decade ago. It is what shapes the inherited genetic material. I believe it to be the decisive factor in determining whether the impairments of ADD will or will not appear in a child.

Many variables will influence the particular environment a child experiences. Birth order, for one, automatically places siblings in dissimilar situations. The older sibling has to suffer the pain of seeing parental love and attention directed toward an intruder. The younger sibling may need to learn survival in an environment that harbors a stronger, potentially hostile rival, and never comes

to know either the special status or the burden of being an only child. The full weight of unconscious parental expectations is far more likely to fall on the firstborn. Historical studies of birth order have established it as an important influence on the shaping of the personality, comparable with sex.[6]

The parents' economic situation may be better around the birth of one child than when other children are born. Or, as in the case of my family of origin, historical or social circumstances may have enormous consequences on the parents' emotional states and therefore on the personalities of their children. I was born in 1944 to Jewish parents in Budapest, Hungary, having made the miscalculation of entering the world two months before the Nazi occupation of my birthplace, over a year before the end of World War II. The first of my two brothers was born two and a half years later, during a time of peace, optimism and immense emotional relief. It goes without saying that the psychological equilibrium of my parents would have changed dramatically between my birth and that of my brother, as would the degree of anxiety they transmitted to their sons.

The younger of my brothers was born in Canada, less than two years after our family settled here as penniless refugees. We had fled Hungary after the 1956 revolution, when my parents, then close to middle age, decided to leave the insecurities and upheavals of Eastern Europe behind forever. Fortunately perhaps, they could not have foreseen the difficulties of adjusting to a new life on a new continent. Their third son arrived in the midst of economic hardship and uncertainty about the future. My mother recalls that she wept throughout the nine months of her pregnancy, and she still has feelings of guilt about the deep postpartum depression she suffered during the first year of her youngest son's life.

Three brothers and, I would say, three different sets of parents. I do not believe it is coincidental that my youngest brother and I have both been treated for depression and attention deficit disorder. Our middle brother has not.

Even without world wars, revolutions and emigration, siblings

growing up in the same home almost never share the same environment. More accurately, brothers and sisters share some environments—usually the less important ones—but they rarely share the one single environment that has the most powerful impact on personality formation. They may live in the same house, eat the same kinds of food, partake in many of the same activities. These are environments of secondary importance. Of all environments, the one that most profoundly shapes the human personality is the invisible one: the emotional atmosphere in which the child lives during the critical early years of brain development. The invisible environment has little to do with parenting philosophies or parenting style. It is a matter of intangibles, foremost among them being the parents' relationship with each other and their emotional balance as individuals. These, too, can vary significantly from the birth of one child to the arrival of another. Psychological tension in the parents' lives during the child's infancy is, I am convinced, a major and universal influence on the subsequent emergence of ADD. We will return to it in later chapters.

A hidden factor of great importance is a parent's unconscious attitude toward a child: what, or whom, on the deepest level, the child represents for the parents; the degree to which the parents see themselves in the child; the needs parents may have that they subliminally hope the child will meet.

For the infant there exists no abstract, "out-there" reality. The emotional milieu with which we surround the child is the world as he experiences it. In the words of the child psychiatrist and researcher Margaret Mahler, for the newborn, the parent is "the principal representative of the world."[7] To the infant and toddler, the world reveals itself in the image of the parent: in eye contact, intensity of glance, body language, tone of voice and, above all, in the day-to-day joy or emotional fatigue exhibited in the presence of the child. Whatever a parent's intention, these are the means by which the child receives his or her most formative communications. Although they will be of paramount importance for development of the child's personality, these subtle and often

unconscious influences will be missed on psychological questionnaires or observations of parents in clinical settings. There is no way to measure a softening or an edge of anxiety in the voice, the warmth of a smile or the depth of furrows on a brow. We have no instruments to gauge the tension in a father's body as he holds his infant or to record whether a mother's gaze is clouded by worry or clear with calm anticipation.

It may be said that no two children have exactly the same parents, in that the *parenting* they each receive may vary in highly significant ways. Whatever the hopes, wishes or intentions of the parent, the child does not experience the parent directly: *the child experiences the parenting*. I have known two siblings to disagree vehemently about their father's personality during their childhood. Neither has to be wrong if we understand that they did not receive the same *fathering*, which is what formed their experience of the father. I have even seen subtly but significantly different mothering given to a pair of identical twins.

In the case of the Gilmores, two of the four brothers—Gary and Galen—turned out "bad" and came to violent ends, and the other two—Frank and Mikal—with great difficulty managed to gain a sense of themselves as self-respecting human beings. When they looked back on their childhoods, Frank and Mikal clearly recognized that their unfortunate siblings had been given their parents' darker sides, while they themselves received what little lightness there was in their father and mother.

The effects of the environment on brain development and personality formation vary from child to child. As we see, these influences are different to begin with. They are also acting on different individuals. How the infant reacts to the environment has a major impact on the nature of his experience of the world. It would be virtually impossible for two children to inhabit the same environment, even if their worlds could be exactly matched to the minutest detail.

7

Emotional Allergies: ADD and Sensitivity

If a mother has eight children, there are eight mothers. This is not simply because of the fact that the mother was different in her attributes to each of the eight. If she could have been the same with each...each child would have had his or her own mother seen through individual eyes.

—D. W. WINNICOTT, F.R.C.P., *Home is Where We Start From*

SUPPERTIME. THE EIGHT-year-old daughter is taking her time leaving her toy or book or reveries. "Hurry up. We want to eat," the father says, tense with hunger and work overload.

The daughter covers her ears. "Don't yell at me," she complains.

"I am not yelling," the man answers, this time hearing himself raise his voice.

The child's face turns into a picture of pain and despair. "Mommy, Daddy's being mean to me," she cries.

If the decibel count in that kitchen had been measured when the father first instructed his daughter to hurry, it would not have registered at levels most people would define as yelling. The daughter's reaction, however, is genuine. She picks up, senses, experiences the tension in the father's voice, the edge of controlled impatience and frustration. That is what is translated in her brain as "yelling." She is feeling exactly the same fear and outrage as another child would if shouted at in an angry manner. It is a matter of sensitivity, of the degree of reactivity to the environment. This child is emotionally hypersensitive.

The derivation of *sensitivity* is from the Latin word *sensir*, "to feel." Degrees of sensitivity reflect degrees of feeling. Of the various *Oxford Dictionary* definitions of *sensitive*, it will be useful to keep three in mind. Each is exquisitely apt as a description of the ADD child: *1. Very open to or acutely affected by external stimuli or mental impressions. 2. Easily offended, or emotionally hurt. 3. (As of an instrument) responsive to or recording small changes.* The word has another connotation, that of being empathetic, respectful of other people's feelings. The two meanings may coexist in the same individual, but not in every case. Some of the most sensitive people in terms of how they react may be the least mindful of the feelings of others.

Some human beings are hyperreactive. A relatively negligible stimulus, or what to other people would seem negligible, sets off in them an intense reaction. When this happens in response to physical stimuli, we say the person is allergic. Someone allergic to, say, bee venom may choke, wheeze and gasp for air when stung. The small airways in the lungs may go into spasm, tissues in the throat may swell, the heartbeat may become irregular. His life may be in peril. The nonallergic person, had she been stung by the same bee, would experience no more than a momentary pain, a welt, an irritating itch. Was it the bee sting that sent the first victim into physiological crisis? Not directly. It was his own physiological responses that brought him close to death. More accurately, it was the combination of stimulus and reaction. The precise medical term for an allergy, for this hyperreactivity, is *hypersensitivity*.

People with ADD are hypersensitive. That is not a fault or a weakness of theirs, it is how they were born. It is their inborn temperament. That, primarily, is what is hereditary about ADD. Genetic inheritance by itself cannot account for the presence of ADD features in people, but heredity can make it far more likely that these features will emerge in a given individual, depending on circumstances. It is sensitivity, not a disorder, that is transmitted through heredity. In most cases, ADD is caused by the impact of the environment on particularly sensitive infants.

Sensitivity is the reason why allergies are more common among ADD children than in the rest of the population. It is well known, and borne out again and again in clinical practice, that children with ADD are more likely than their non-ADD counterparts to have a history of frequent colds, upper respiratory infections, ear infections, asthma, eczema and allergies, a fact interpreted by some as evidence that ADD is due to allergies. Although the flare-up of allergies can certainly aggravate ADD symptoms, the one does not cause the other. They both are expressions of the same underlying inborn trait: sensitivity. Since emotionally hypersensitive reactions are no less physiological than the body's allergic responses to physical substances, we may say truthfully that people with ADD have emotional allergies.

Almost any parent with an ADD child, or any adult living with an ADD spouse, will have noticed in the ADD person a touchiness, a "thin skin." People with ADD are forever told that they are "too sensitive" or that they should stop being "so touchy." One might as well advise a child with hay fever to stop being "so allergic."

With its usual wisdom, everyday language has found an accurate description of hypersensitivity when it speaks of someone having a thin skin. If one had an area on one's thigh with part of the epidermis destroyed by, say, scalding hot water, one literally would have a thin skin: the nerve endings would be closer to the surface. A slight gust of air might cause a highly unpleasant sensation, even pain, whereas surfaces with full-thickness skin would feel little or nothing. The emotionally sensitive person lives, as it

were, with the nerve endings that send emotional stimuli to the brain centers very close to the surface. Like the exposed nerve endings in scalded skin, they are very easily irritated. Hence, my daughter's complaint that I was yelling. Of course, I was the short-tempered father in the anecdote. The suppertime set-to used to be familiar in our home.

Parents, teachers and doctors may doubt a child's reports of his sensations. Some hypersensitive children, feeling physical pain or discomfort, will express what to others may seem an excessive and exaggerated distress. They are accused of malingering or playacting or of looking for attention. In fact, there is no dissimulation in their behavior around pain or discomfort, only, in a phrase of Friedrich Nietzsche's, "a refined susceptibility to pain." Sensitivity is affected by emotional states. People's pain tolerance is lower when they feel anxious or depressed, partly because of changes in stress hormone levels and in the levels of endorphins, the body's innate painkillers.

Sensitive children come to be called "difficult" because adults have trouble understanding their temperament and because parenting methods that work with other children are frustratingly inadequate with this group. Like the related phrase "terrible twos," "difficult child" shows grown-up bias. In the child's experience, it is the adult who is ornery. Were children the arbiters of language, we would hear of the "difficult parent" and the "terrible thirties."

Physiological differences in the human nervous system help explain differences in levels of emotional reactivity from one child to the other. In some children, the nervous system is always in a state of hair-trigger alert. Researchers at the University of Washington, Seattle, measured the electrical activity of an important nerve, the vagus nerve, in five-month-old babies.[1] (The vagus connects the central nervous system with the heart, the lungs and the stomach.) Infants with a higher baseline "tone" in the vagus nerve were also "more emotionally reactive to both positive and mildly stressful stimuli." These same infants at fourteen months were more reactive to maternal separation.

Like hypersensitive instruments, sensitive children register and

record even minute changes in their emotional environment. It is not a matter of choice for them; their nervous systems react. It is as if they had invisible antennae projecting in every direction, picking up and conducting into their bodies and their minds the psychic emanations around them. They may have no conscious knowledge of this, any more than an instrument is consciously aware of what measurements it is registering. Unlike instruments, however, the sensory equipment of human beings is not easily shut off. My wife and I learned to recognize our daughter's moods and behaviors as real-time, instantaneous computer printouts of the psychological atmosphere in our home. If we wanted to know how we were doing as individuals or as a couple, we needed only check the facial expressions and emotional responses of our daughter. What was recorded there did not always reassure us.

Abdominal cramps in sensitive children are often clues to unresolved tensions in the family environment. They are common and all too frequently misinterpreted. These are the children who go pale with "inexplicable" tummy aches and are dragged from doctor to doctor, from clinic to emergency ward, from specialist to specialist, subjected to examinations, tests, X-rays and over and over again are pronounced "perfectly healthy." The parents are assured there is no reason for the pain. There is reason. Their child's body is a barometer for the stresses on the whole family system, his symptoms the markings on a minutely calibrated instrument.

As pointed out in chapter 6, there are a small number of debilitating conditions with a strong genetic basis, such as muscular dystrophy or Huntington's disease. These are rare, affecting about one person in ten thousand or even fewer. They do not pose a significant threat to the survival of the species. If, however, we add up the numbers of people plagued by depression or ADD or the other common psychological problems people in this society struggle with, including alcoholism and anxiety, we will have identified no less than a third of the North American population. Genetic explanations for these conditions assume that after millions of years of evolution, nature would permit a very large number of disordered

genes, handicapping a third of humankind, to pass through the screen of natural selection—a highly unlikely proposition.

We face no such difficulty if we see that what is being transmitted genetically is not ADD or its equally ill-mannered and discombobulating relatives, but *sensitivity*. The existence of sensitive people is an advantage for humankind because it is this group that best expresses humanity's creative urges and needs. Through their instinctual responses the world is best interpreted. Under normal circumstances, they are artists or artisans, seekers, inventors, shamans, poets, prophets. There would be valid and powerful evolutionary reasons for the survival of genetic material coding for sensitivity. It is not diseases that are being inherited but a trait of intrinsic survival value to human beings. Sensitivity is transmuted into suffering and disorders only when the world is unable to heed the exquisitely tuned physiological and psychic responses of the sensitive individual.

ADD is not a natural state. It is, to adapt a famous phrase of Sigmund Freud's, one of civilization's discontents.

8

A Surrealistic Choreography

One of the most striking peculiarities of the human brain is the great development of the frontal lobes—they are much less developed in other primates and hardly evident at all in other mammals. They are the part of the brain that grows and develops most after birth.

—OLIVER SACKS, M.D., *An Anthropologist on Mars*

THE HUMAN BRAIN is the most complex entity in the universe. It has between fifty and one hundred billion nerve cells, or neurons, each branched to form thousands of possible connections with other nerve cells. It has been estimated that laid end to end, the nerve cables of a single human brain would extend into a line several hundred thousand miles long. The total number of connections, or *synapses*, is in the trillions.[1] The parallel and simultaneous activity of innumerable brain circuits, and networks of circuits, produces millions of firing patterns each and every second of our lives. The brain has well been described as "a supersystem of

systems." Even though fully half of the roughly hundred thousand genes in the human organism are dedicated to the central nervous system, the genetic code simply cannot carry enough information to predetermine the infinite number of potential brain circuits. For this reason alone, biological heredity could not by itself account for the densely intertwined psychology and neurophysiology of attention deficit disorder.

Experience in the world determines the fine wiring of the brain. As the neurologist and neuroscientist Antonio Damasio puts it, "Much of each brain's circuitry, at any given moment in adult life, is individual and unique, truly reflective of that particular organism's history and circumstances."[2] This is no less true of children and infants. Not even in the brains of genetically identical twins will the same patterns be found in the shape of nerve cells or the numbers and configuration of their synapses with other neurons.

The microcircuitry of the brain is formatted by influences during the first few years of life, a period when the human brain undergoes astonishingly rapid growth. Five-sixths of the branching of nerve cells in the brain occurs after birth. At times in the first year of life, new synapses are being established at a rate of three billion a second. In large part, each infant's individual experiences in the early years determine which brain structures will develop and how well, and which nerve centers will be connected with which other nerve centers, and establish the networks controlling behavior.[3] The intricately programmed interactions between heredity and environment that make for the development of the human brain are determined by a "fantastic, almost surrealistically complex choreography," in the apt phrase of Dr. J. S. Grotstein of the department of psychiatry at UCLA. Attention deficit disorder results from the miswiring of brain circuits, in susceptible infants, during this crucial period of growth.

Of all mammals, the human animal has the least mature brain at birth. Early in their infancy, other animals perform tasks far beyond the capabilities of humans for many months. A horse can walk on the first day of life; infant apes cling to mother's fur within a few

weeks of birth. Human beings are able to coordinate the visual skills, muscle control, balance and orientation in space required for comparable activities only near the end of the first year.

In the period following birth, the human brain, unlike that of our closest evolutionary relative, the chimpanzee, continues to grow at the same rate as in the womb. Whereas the chimpanzee brain will no more than double from birth to reach its adult size, the brain mass of humans will have *tripled* by age four. By adulthood, the size of our brain will have *quadrupled*, meaning that fully three-quarters of our brain growth takes place outside the womb following birth, with most of this increase occurring in the early years.

One way to see this is as a compromise negotiated by nature. We were permitted to walk, freeing our forelimbs to evolve into arms and hands capable of many delicate and complicated activities—a development that gave impetus to a large expansion in brain size, particularly of the frontal lobes. These lobes coordinate the movements of the hands. They also perform the problem solving and the social and language skills that have given humankind abilities to thrive in a wide variety of habitats. Were we born with our wiring rigidly fixed by heredity, the frontal lobes would be far more limited in their capacity to learn and to adapt to the many different possible environments that human beings inhabit.

To accommodate our upright stance, the human pelvis had to narrow, so growth inside the womb longer than nine months would have resulted in infants too large to be born safely. Already at the end of the nine months of human gestation, the head is the largest part of the body, the one most likely to get stuck in our journey through the birth canal. The bargain forced on our evolutionary ancestors was that the tremendously large human brain has to develop outside the relatively safe environment of the womb, highly vulnerable to potentially adverse circumstances.

According to the latest insights of modern neuroscience, brain development in the human infant involves a process of competition that has been described as "neural Darwinism."[4] Nerve cells,

circuits, networks and systems of networks vie with one another for survival. The neurons and connections most useful to the organism's survival in its given environment are maintained. Others wither and die. Nerve pathways lacking the full conditions for growth will not develop, or will develop dysfunctionally and incompletely. The stores of neurochemicals that are underutilized diminish, and the brain's capacity to manufacture them declines. By the elimination of unused cells and synapses, and by the formation of new ones favored by the environment, specialized circuits gradually develop that conduct the varied and multiple activities of the human brain.

Neural Darwinism means that our genetic potential for brain development can find its full expression only if circumstances are favorable. To understand this, we need only imagine an infant kept in a dark room, held, physically cared for and fed, but never spoken to. After a year of such deprivation, the brain of this infant would not be comparable to those of other infants, no matter what her inherited potential. Despite perfectly good eyes at birth and healthy nerves to conduct visual images to the brain, the thirty or so neurological units that together make up visual sense would not develop. Even the neurological components of vision present at birth would atrophy and become useless if this child never saw light for about five years. Irreversible blindness would be the result. If we surrounded the child with silence for the first ten years, he would never be able to learn human speech. Attention deficit disorder is also an example of how the neural circuitry and biochemistry of the brain may be held back from developing optimally when appropriate input from the environment is interfered with. What, then, are the optimal conditions for full brain development?

The three conditions without which healthy growth does not take place can be taken for granted in the matrix of the womb: nutrition, a physically secure environment and the unbroken relationship with a safe, ever-present maternal organism. The word *matrix* is derived from the Latin for "womb," itself derived from the word for "mother." The womb is mother, and in many

respects the mother remains the womb, even following birth. In the womb environment, no action or reaction on the developing infant's part is required for the provision of any of his needs. Life in the womb is surely the prototype of life in the Garden of Eden where nothing can possibly be lacking, nothing has to be worked for. If there is no consciousness—we have not yet eaten of the Tree of Knowledge—there is also no deprivation or anxiety.

Except in conditions of extreme poverty unusual in the industrialized world, although not unknown, the nutritional needs and shelter requirements of infants are more or less satisfied. The third prime requirement, a secure, safe and not overly stressed emotional atmosphere, is the one most likely to be disrupted in Western societies.

The human infant lacks the capacity to follow or cling to the parent soon after being born, and is neurologically and biochemically underdeveloped in many other ways. The first nine months or so of extrauterine life seem to have been intended by nature as the second part of gestation. The anthropologist Ashley Montagu has called this phase *exterogestation*, gestation outside the maternal body.[5] During this period, the security of the womb must be provided by the parenting environment. To allow for the maturation of the brain and nervous system that in other species occurs in the uterus, the attachment that was until birth directly physical now needs to be continued on both physical and emotional levels. Physically and psychologically, the parenting environment must contain and hold the infant as securely as she was held in the womb.

For the second nine months of gestation, nature does provide a near-substitute for the direct umbilical connection: breast-feeding. Apart from its irreplaceable nutritional value and the immune protection it gives the infant, breast-feeding serves as a transitional stage from unbroken physical attachment to complete separation from the mother's body. Now outside the matrix of the womb, the infant is nevertheless held close to the warmth of the maternal body from which nourishment continues to flow. Breast-feeding

also deepens the mother's feeling of connectedness to the baby, enhancing the emotionally symbiotic bonding relationship. No doubt the decline of breast-feeding, particularly accelerated in North America, has contributed to the emotional insecurities so prevalent in industrialized countries.

Even more than breast-feeding, healthy brain development requires emotional security and warmth in the infant's environment. This security is more than the love and best possible intentions of the parents. It depends also on a less controllable variable: their freedom from stresses that can undermine their psychological equilibrium. A calm and consistent emotional milieu throughout infancy is an essential requirement for the wiring of the neurophysiological circuits of self-regulation. When interfered with, as it often is in our society, brain development is adversely affected. ADD is one of the possible consequences.

9

Attunement and Attachment

From early infancy, it appears that our ability to regulate emotional states depends upon the experience of feeling that a significant person in our life is simultaneously experiencing a similar state of mind.

—DANIEL J. SIEGEL, M.D.

THE AREAS OF THE CORTEX responsible for attention and self-regulation develop in response to the emotional interaction with the person whom we may call the mothering figure. Usually this is the birth mother, but it may be another person, male or female, depending on circumstances. Although, for the sake of convenience, I will at times refer to this person only as the mother, the word should always be understood to refer to whoever the primary nurturing figure may be—father, mother, or grandparent, foster parent or adoptive parent of either gender. Because the formation of the child's brain circuits is influenced by the mother's emotional states, I believe that ADD originates in stresses that affect the mothering

parent's emotional interactions with the infant. They cause the disrupted electrical and chemical circuitry of ADD. Attachment and attunement, two crucial aspects of the infant-parent relationship, are the determining factors. They are the subject of this chapter.

The right hemisphere of the mother's brain, the side where our unconscious emotions reside, programs the infant's right hemisphere. In the early months, the most important communications between mother and infant are unconscious ones. Incapable of deciphering the meaning of words, the infant receives messages that are purely emotional. They are conveyed by the mother's gaze, her tone of voice and her body language, all of which reflect her unconscious internal emotional environment. Anything that threatens the mother's emotional security may disrupt the developing electrical wiring and chemical supplies of the infant brain's emotion-regulating and attention-allocating systems.*

Within minutes following birth, the mother's odors stimulate the branching of millions of nerve cells in the newborn's brain. A six-day-old infant can already distinguish the scent of his mother from that of other women. Later on, visual inputs associated with emotions gradually take over as the major influences.

By two to seven weeks, the infant will orient toward the mother's face in preference to a stranger's—and also in preference to the father's, unless the father is the mothering adult. At seventeen weeks, the infant's gaze follows the mother's eyes more closely than her mouth movements, thus fixating on what has been called "the visible portion of the mother's central nervous system." The infant's right brain reads the mother's right brain during intense eye-to-eye mutual gaze interactions. As an article in *Scientific American* expressed it, "Embryologically and anatomically the eye is an extension of the brain; it is almost as if a portion of the brain were in plain sight."[1] The eyes communicate eloquently the mother's unconscious emotional states:

* The circuitry and brain chemistry involved are described in the next chapter.

> [O]ne person uses another's pupil size as a source of information about that person's feelings or attitudes; this process usually occurs at unconscious levels. Dilated pupils occur in states of pleasure and are an indicator of "interest"... Experiments have shown that women's eyes dilate in response to a picture of a baby. Most importantly...viewing enlarged dilated pupils elicits larger pupils in the observer. In a developmental study, infants smiled more when a female experimenter's eyes were dilated rather than constricted...

Everyone has had the experience of suddenly feeling intense physiological and psychological shifts internally at trading glances with another person; such shifts can be exquisitely pleasurable or unpleasant. How one person gazes at another can alter the other's electrical brain patterns, as registered by EEGs, and may also cause physiological changes in the body. The newborn is highly susceptible to such influences, with a direct effect on the maturation of brain structures.

The effects of maternal moods on the electrical circuitry of the infant's brain were demonstrated by a study at the University of Washington, Seattle.[2] Positive emotions are associated with increased electrical activity in the left hemisphere. It is known that depression in adults is associated with *decreased* electrical activity in the circuitry of the left hemisphere. With this in mind, the Seattle study compared the EEGs of two groups of infants: one group whose mothers had symptoms of postpartum depression, the other whose mothers did not. "During playful interactions with the mothers designed to elicit positive emotion," the researchers reported, "infants of non-depressed mothers showed greater left than right frontal brain activation." The infants of depressed mothers "failed to show differential hemispheric activation," meaning that the left-side brain activity one would anticipate from positive, joyful infant-mother exchanges did not occur—despite the mothers' best efforts. Significantly, these effects were noted only in the frontal areas of the brain, where the centers for the self-regulation

of emotion are located. In addition to EEG changes, infants of depressed mothers exhibit decreased activity levels, gaze aversion, less positive emotion and greater irritability.

Maternal depression is associated with diminished infant attention spans. Summarizing a number of British studies, Dale F. Hay, a researcher at the University of Cambridge, suggests "that the experience of the mother's depression in the first months of life may disrupt naturally occurring social processes that entrain and regulate the infant's developing capacities for attention."[3]

Just how important a close moment-to-moment connection between mother and infant can be was illustrated by a cleverly designed study, known as the "double TV experiment," in which infants and mothers interacted via a closed-circuit television system. In separate rooms, infant and mother observed each other and, on "live feed," communicated by means of the universal infant-mother language: gestures, sounds, smiles, facial expressions. The infants were happy during this phase of the experiment. "When the infants were unknowingly replayed the 'happy responses' from the mother recorded from the prior minute," writes the UCLA child psychiatrist Daniel J. Siegel, "they still became as profoundly distressed as infants do in the classic 'flat face' experiments in which mothers-in-person gave no facial emotional response to their infant's bid for attunement."[4]

Why were the infants distressed despite the sight of their mothers' happy and friendly faces? Because happy and friendly are not enough. What they needed were signals that the mother is aligned with, responsive to and participating in their mental states from moment to moment. All that was lacking in the instant video replay, during which infants saw their mother's face unresponsive to the messages they, the infants, were sending out. This sharing of emotional spaces is called *attunement*.[5] Emotional stress on the mother interferes with infant brain development because it tends to interfere with the attunement contact.

Attunement is necessary for the normal development of the brain pathways and neurochemical apparatus of attention and

emotional self-regulation. It is a finely calibrated process requiring that the parent remain herself in a relatively nonstressed, nonanxious, nondepressed state of mind. Its clearest expression is the rapturous mutual gaze infant and mother direct at each other, locked in a private and special emotional realm, from which, at that moment, the rest of the world is as completely excluded as from the womb.

Attunement does not mean mechanically imitating the infant. It cannot be simulated, even with the best of goodwill. As we all know, there are differences between a real smile and a staged smile. The muscles of smiling are exactly the same in each case, but the signals that set the smile muscles to work do not come from the same centers in the brain. As a consequence, those muscles respond differently to the signals, depending on their origin. This is why only very good actors can mimic a genuine, heartfelt smile. The attunement process is far too subtle to be maintained by a simple act of will on the part of the parent. Infants, particularly sensitive infants, intuit the difference between a parent's real psychological states and her attempts to soothe and protect the infant by means of feigned emotional expressions. A loving parent who is feeling depressed or anxious may try to hide that fact from the infant, but the effort is futile. In fact, it is much easier to fool an adult with forced emotion than a baby. The emotional sensory radar of the infant has not yet been scrambled. It reads feelings clearly. They cannot be hidden from the infant behind a screen of words, or camouflaged by well-meant but forced gestures. It is unfortunate but true that we grow far more stupid than that by the time we reach adulthood.

In attunement, it is the infant who leads and the mother who follows. "Where their roles differ is in the timing of their responses," writes John Bowlby, one of the century's great psychiatric researchers.[6] The infant initiates the interaction or withdraws from it according to his own rhythms, Bowlby found, while the "mother regulates her behaviour so that it meshes with his... Thus she lets him call the tune and by a skillful interweaving of her own

responses with his creates a dialogue." The tense or depressed mothering adult will not be able to accompany the infant into relaxed, happy spaces. He may also not fully pick up signs of the infant's emotional distress, or may not be able to respond to them as effectively as he would wish. The ADD child's difficulty reading social cues likely originates from her relationship cues not being read by the nurturing adult, who was distracted by stress.

In the attunement interaction, not only does the mother follow the child, but she also permits the child to temporarily interrupt contact. When the interaction reaches a certain stage of intensity for the infant, he will look away to avoid an uncomfortably high level of arousal. Another interaction will then begin. A mother who is anxious may react with alarm when the infant breaks off contact, may try to stimulate him, to draw him back into the interaction. Then the infant's nervous system is not allowed to "cool down," and the attunement relationship is hampered.

Infants whose caregivers were too stressed, for whatever reason, to give them the necessary attunement contact will grow up with a chronic tendency to feel alone with their emotions, to have a sense—rightly or wrongly—that no one can share how they feel, that no one can "understand."

Attunement is the quintessential component of a larger process, called *attachment*.[7] Attachment is simply our need to be close to somebody. It represents the absolute need of the utterly and helplessly vulnerable human infant for secure closeness with at least one nourishing, protective and constantly available parenting figure. Essential for survival, the drive for attachment is part of the very nature of warm-blooded animals in infancy, especially of mammals.

In human beings, attachment is a driving force of behavior for longer than in any other animal. For most of us it is present throughout our lives, although we may transfer our attachment need from one person—our parent—to another—say, a spouse or even a child. We may also attempt to satisfy the lack of the human contact we crave by various other means, such as addictions, for

example, or perhaps fanatical religiosity or the virtual reality of the Internet. Much of popular culture, from novels to movies to rock or country music, expresses nothing but the joys or the sorrows flowing from satisfactions or disappointments in our attachment relationships. Most parents extend to their children some mixture of loving and hurtful behavior, of wise parenting and unskillful, clumsy parenting. The proportions vary from family to family, from parent to parent. Those ADD children whose needs for warm parental contact are most frustrated grow up to be adults with the most severe cases of ADD.

Already at only a few months of age, an infant will register by facial expression his dejection at the mother's unconscious emotional withdrawal, despite the mother's continued physical presence. "(The infant) takes delight in Mommy's attention," writes Stanley Greenspan, "and knows when that source of delight is missing. If Mom becomes preoccupied or distracted while playing with the baby, sadness or dismay settles in on the little face."[8]

10

The Footprints of Infancy

The mind emanates from the interface between neurophysiological processes and interpersonal relationships. Experience selectively shapes genetic neuronal potential and thus directly influences the structure and function of the brain.

— DANIEL J. SIEGEL, M.D.

BEHIND THE FOREHEAD in the vicinity of the right eye is where one of the most important regulatory centers in the brain is located: the orbitofrontal cortex.[1] It is part of the prefrontal cortex, that area of the gray matter most involved in social intelligence, impulse control and attention. It is also important in short-term working memory. The orbitofrontal cortex—so named because of its proximity to the eye socket, known as the orbit—is more developed on the right side and appears to dominate its counterpart in the left hemisphere.

A complex condition like ADD cannot be traced to just one part

of the brain. Many circuits and systems must be involved. According to a lot of recent evidence, however, disturbances of the orbitofrontal cortex are, indeed, implicated in disorders of impulse inhibition and emotional self-regulation, including ADD. It is probably here that the neurophysiological effects of stressed attunement and attachment are most pronounced.

Nature's goal for human growth is for the eventual maturation of a self-motivated, self-regulated and self-reliant adult. The infant lacks these attributes. We may say that the natural agenda is really the transformation of regulation from dependence on another individual to independence, from external regulation to internal regulation. This shift from external to internal regulation requires the development of the prefrontal cortex, the cortex in the very anterior portion of the brain, including and especially the orbitofrontal cortex.

The right orbitofrontal cortex, which for the sake of brevity we will call the OFC, has connections with virtually every other part of the cortex. It also has rich connections with the lower brain structures, where the body's internal physiological states are controlled and monitored, and where the most primitive and powerful emotions such as fear and rage are generated. It is at the center of the brain's reward and motivation apparatus and contains more of the reward chemicals associated with pleasure and joy—dopamine and endorphins—than almost any other area of the cortex.

Via its connections with the vision centers of the cortex, the OFC plays a role in visual-spatial orientation, the locating of objects in space. When visual-spatial orientation is impaired, a person tends to bump his head a lot or run into people unseeingly and have difficulty following physical directions—all features of ADD I am intimately familiar with.

The OFC has a major role in the control of attention. From all the information about the external environment and internal body states entering our brain, the OFC helps to pick out what to focus on. While the explicit meaning of words spoken is analyzed in the left hemisphere, the right OFC interprets the emotional content of

communications—the other person's body language, eye movements and tone of voice. It carries out a constant and instantaneous computation of the emotional significance of situations. It is deeply concerned with the assessment of relationships between the self and others. According to a number of studies, it is "dominant for the processing, expression, and regulation of emotional information."[2]

The OFC also functions in impulse control, helping to inhibit the lower centres in the brain where urgent emotional drives originate. When it is working smoothly, it can delay emotional reactions long enough to allow mature, more sophisticated responses to emerge. When its connections are disrupted, it lacks this capacity. At such times primitive, unprocessed emotions will flood our minds, overwhelm our thinking processes and control our behavior.

Finally, the OFC records and stores the emotional effects of experiences, first and foremost the infant's interactions with his or her primary caregivers during the early months and years. Its imprinting of the earliest interactions with the primary caregivers is the unconscious model from which all later emotional reactions and interactions will be formed. Groups of neurons in the OFC encode the emotional footprints of these important experiences—footprints in which, willy-nilly, we tend to follow later in life, again and again and again.

The great Canadian researcher Donald Hebb showed that groups of neurons that have fired together once are more likely to fire simultaneously in the future. This Hebbian principle has been expressed as "neurons that fire together wire together." The early emotional imprinting is encoded in the form of potential neuronal patterns: groups of nerve cells primed to fire together. We experience them later in life when we find to our surprise that some relatively minor stimulus, being cut off in traffic, for example, triggers in us an irrational rage, leaving us scratching our head and wondering, What was that about? It was about the early imprinting of the OFC with the rage and frustration of the infant and toddler, and about the Hebbian principle. Each time we scream at

someone in traffic, we are telling a story from the earliest part of our life.

A vast body of research supports this understanding of the functions of the right prefrontal cortex. Most dramatic to observe are the deficiencies and impairments suffered by people who have been injured in this area of the brain.[3] Their behavior and emotional reactions are like a textbook description of ADD. Among other ADD-like features, these so-called prefrontal patients often digress and have to be frequently reminded to finish a line of thought; are easily distracted; when listening, will often shift attention to whatever snippet of speech catches their interest; during tasks will often seem to lose track of what the instructions were; will be given to childish emotional outbursts; will have difficulty inhibiting their physical impulses; will find it nearly impossible to learn from experience.

Sustaining physical damage, such as an injury to the brain, is not the only way that the chemical and electrical functions of the prefrontal cortex may become disrupted. In ADD there is no brain damage, but there is impaired brain development. As I wrote in an earlier chapter, *it is not that a disorder develops, but that certain important brain circuits do not develop. Interference with the conditions required for the healthy development of the prefrontal cortex, I believe, accounts for virtually all cases of ADD.*

Emotional interactions stimulate or inhibit the growth of nerve cells and circuits by complicated processes that involve the release of natural chemicals. To give a somewhat simplified example, when "happy" events are experienced by the infant, endorphins—"reward chemicals," the brain's natural opioids—are released. Endorphins encourage the growth of nerve cells and of connections between them. Conversely, in animal studies, chronically high levels of stress hormones such as cortisol have been shown to cause important brain centers to shrink.

Emotions affect not only the release of brain chemicals in the short term but also the long-term balance of neurotransmitters, the molecular messengers telegraphing electrical impulses from one

nerve cell to another. Just as the infant's early interactions with the nurturing caregivers help to shape the structure of brain centers and circuits, so, too, do they play a role in determining the chemistry of the brain. Throughout the human life span there remains a constant two-way interaction between psychological states and the neurochemistry of the frontal lobes, a fact that many doctors do not pay enough attention to. One result is the overreliance on medications in the treatment of mental disorders. Modern psychiatry is doing too much listening to Prozac and not enough listening to human beings; people's life histories should be given at least as much importance as the chemistry of their brains.

The dominant tendency is to explain mental conditions by deficiencies of the brain's chemical messengers, the neurotransmitters. As Daniel J. Siegel has sharply remarked, "We hear it said everywhere these days that the experience of human beings comes from their chemicals." Depression, according to the simple biochemical model, is due to a lack of serotonin—and, it is said, so is excessive aggression. The answer is Prozac, which increases serotonin levels in the brain. Attention deficit is thought to be due in part to an undersupply of dopamine, one of the brain's most important neurotransmitters, crucial to attention and to experiencing reward states. The answer is Ritalin. Just as Prozac elevates serotonin levels, Ritalin or other psychostimulants are thought to increase the availability of dopamine in the brain's prefrontal areas. This is believed to increase motivation and attention by improving the functioning of areas in the prefrontal cortex. Although they carry some truth, such biochemical explanations of complex mental states are dangerous oversimplifications—as the neurologist Antonio Damasio cautions:

> When it comes to explaining behavior and mind, it is not enough to mention neurochemistry... The problem is that it is not the absence or low amount of serotonin *per se* that "causes" certain manifestations. Serotonin is part of an exceedingly complicated mechanism which operates at the level

of molecules, synapses, local circuits, and systems, and in which sociocultural factors, past and present, also intervene powerfully.[4]

The deficiencies and imbalances of brain chemicals are as much effect as cause. They are greatly influenced by emotional experiences. Some experiences deplete the supply of neurotransmitters; other experiences enhance them. In turn, the availability—or lack of availability—of brain chemicals can promote certain behaviors and emotional responses and inhibit others. Once more we see that the relationship between behavior and biology is not a one-way street. As an example, in troops of monkeys the dominant, most successfully aggressive males have been found to have less serotonin than the others. This would seem to prove that low serotonin levels cause aggression. However, the serotonin levels drop only *after* these males achieve dominant status. So while the relative lack of serotonin may help to *maintain* the dominant male's aggressive capacities, it could not have *caused* them. Emotional stress can similarly affect serotonin levels, contributing to symptoms of depression. When we prescribe Prozac, we are not so much treating the biology of inheritance as the biology of living and having experiences in the world.

Environmental influences also affect dopamine. From animal studies, we know that social stimulation is necessary for the growth of the nerve endings that release dopamine and for the growth of receptors that dopamine needs to bind to in order to do its work. In four-month-old monkeys, major alterations of dopamine and other neurotransmitter systems were found after only six days of separation from their mothers. "In these experiments," writes Steven Dubovsky, Professor of Psychiatry and Medicine at the University of Colorado, "loss of an important attachment appears to lead to less of an important neurotransmitter in the brain. Once these circuits stop functioning normally, it becomes more and more difficult to activate the mind."[5]

A neuroscientific study published in 1998 showed that adult

rats whose mothers had given them more licking, grooming and other physical-emotional contact during infancy had more efficient brain circuitry for reducing anxiety, as well as more receptors on nerve cells for the brain's own natural tranquilizing chemicals.[6] In other words, early interactions with the mother shaped the adult rat's neurophysiological capacity to respond to stress. In another study, newborn animals reared in isolation had reduced dopamine activity in their prefrontal cortex—but not in other areas of the brain. That is, emotional stress particularly affects the chemistry of the prefrontal cortex, the center for selective attention, motivation and self-regulation. Given the relative complexity of human emotional interactions, the influence of the infant-parent relationship on human neurochemistry is bound to be even stronger.

In the human infant, the growth of dopamine-rich nerve terminals and the development of dopamine receptors is stimulated by chemicals released in the brain during the experience of joy, the ecstatic joy that comes from the perfectly attuned mother-child mutual gaze interaction. Happy interactions between mother and infant generate motivation and arousal by activating cells in the midbrain that release endorphins, thereby inducing in the infant a joyful, exhilarated state. They also trigger the release of dopamine. Both endorphins and dopamine promote the development of new connections in the prefrontal cortex. Dopamine released from the midbrain also triggers the growth of nerve cells and blood vessels in the right prefrontal cortex and promotes the growth of dopamine receptors. A relative scarcity of such receptors and blood supply is thought to be one of the major physiological dimensions of ADD.

The letters ADD may equally well stand for Attunement Deficit Disorder.